電機機械

§Ch1. 変圧器

① 等效电路
- 一、二側転換
- 2个 T_L 連接

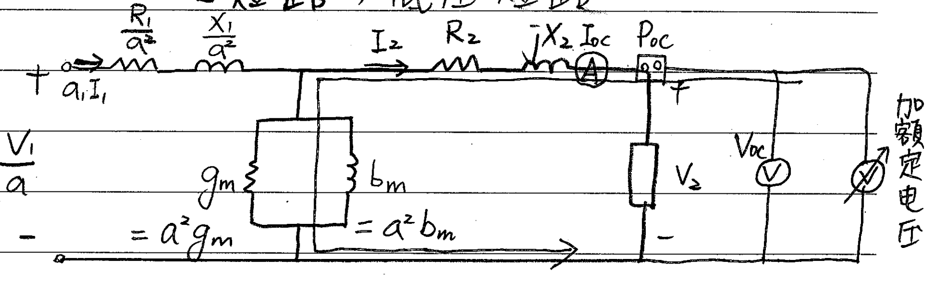
② 標么值 → 單相

③ 电压分接頭 (一次側分接頭)
(調整二次側电压)

$$a_1 = \frac{V_1}{\boxed{V_2}} = \frac{\boxed{N_1}}{N_2}$$

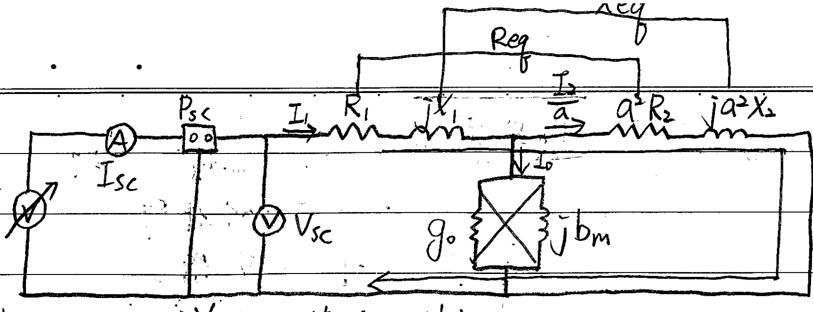
$$\Rightarrow \boxed{\frac{N_1}{N_1'} = \frac{V_2'}{V_2}}$$

④ 試驗
- 開路 ⇒ 高压開路
- 短路 ⇒ 低压短路



$$\begin{cases} Y_0 = \dfrac{I_{oc}}{V_{oc}} & \text{(激磁導納)} \\ G_0 = \dfrac{P_{oc}}{V_{oc}^2} & \text{(电導)} \\ B_0 = \sqrt{Y_0^2 - G_0^2} & \text{(电納)} \end{cases}$$

加压至产生额定电流



$$\begin{cases} Z_{SE} = \dfrac{V_{sc}}{I_{sc}} & \text{(等值阻抗)} \\ R_{eq} = \dfrac{P_{sc}}{I_{sc}^2} & \text{(电阻)} \\ X_{eq} = \sqrt{Z_{SE}^2 - R_{eq}^2} & \text{(电抗)} \end{cases}$$

⑤ 电压調整率 (VR%) ⇒ $VR\% = P\cos\theta \pm q\sin\theta$,

$$P = \frac{I_2 \times R_{eq}}{V_2}, \quad q = \frac{I_2 \times X_{eq}}{V_2}$$

$$\begin{cases} VR\%(\max) = \sqrt{p^2+q^2}, & \cos\theta = \dfrac{p}{\sqrt{p^2+q^2}} \\ VR\%(\min) = 0, & \cos\theta = \dfrac{q}{\sqrt{p^2+q^2}} \end{cases}$$

⑥ 損失，效率

- 銅損
- 鉄損

- 最大效率時負載 $(\frac{1}{m})$
- 全日效率

→ 鉄損 = 銅損

$$P_i = \left(\frac{1}{m}\right)^2 P_{c滿} \Rightarrow \frac{1}{m} = \sqrt{\frac{P_i}{P_{c滿}}}$$

Date . .

⑦ 並聯 ⇒ $\boxed{\text{电压相同}}$

1.) 條件 [單相 ⇒ [一、二側額定电压相同
極性相同
匝数相同
阻抗内角相同 ⇒ 电流槽
代数和 $I_1 = \frac{V}{Z_1} = \frac{V\angle 0^\circ}{Z_1\angle\theta_1}$

$I_L = I_1 + I_2 + I_3$

三相 → [相序相同
相序角相同

2.) 計算： [阻抗.實際值 (Z)
阻抗.標么值 (Z_{pu}) ⇒ 求电流. 容量 (I) (S)

$$I_1 = I_L \times \frac{Y_1 \times (S_{pu1})}{Y_1 + Y_2 + Y_3}$$

(S_1) (S_L) $\times S_{pu1}$ $\times S_{pu2}$ $\times S_{pu3}$

⑧ 三相連接

[Y:
Δ:] 特性 [Y−Y
Δ−Δ
Y−Δ
Δ−Y

☆ [$\boxed{V-V}$ ⇒ $S_{V-V} = \sqrt{3}\, V_p I_p = \sqrt{3}\, V_L I_L$

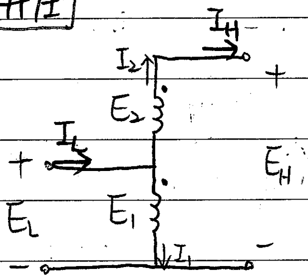
[$V_p = V_L$
$I_p = I_L$

凵−V

※ $\boxed{\begin{gathered} S_{W}/台 = \frac{\sqrt{3}}{2} V_p I_p = 0.866\, V_p I_p \\ \frac{S_{V-V}}{S_{\Delta-\Delta}} = \frac{\sqrt{3}\, V_p I_p}{3\, V_p I_p} = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} = 0.577 \end{gathered}}$

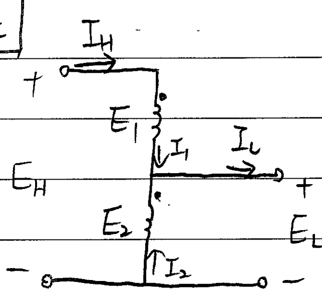
⑨ 自耦 T_L.(單相)

升压



$\boxed{S_{自} = S_{原}\left(1 + \frac{共同电压}{非共同电压}\right)}$

降压



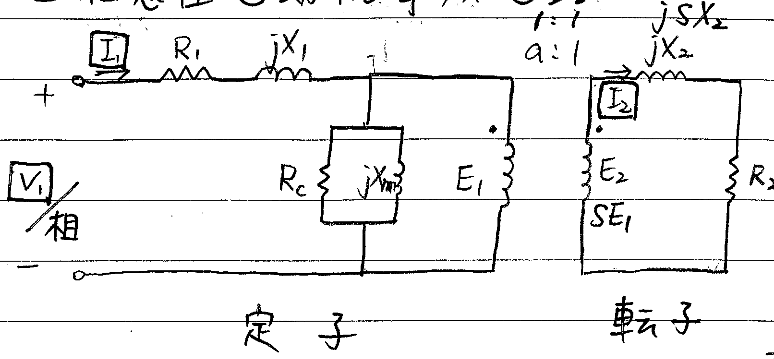
一樣

⑩ 比压器 (P.T.)
→ 降压 T_L (二次側 110V)
→ 二次側电流上升 ⇒ 不可短路

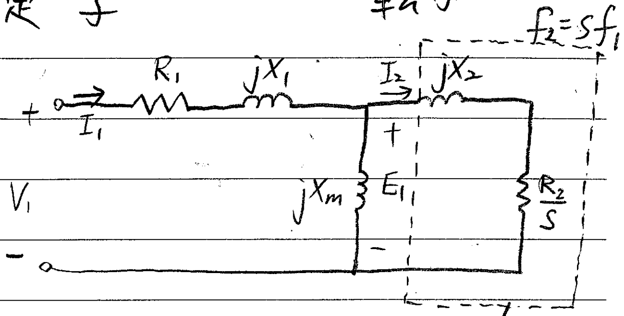
比流器 (C.T.)
→ 降电流 T_L (二次側 5A)
→ 二次側电压上升 ⇒ 不可開路

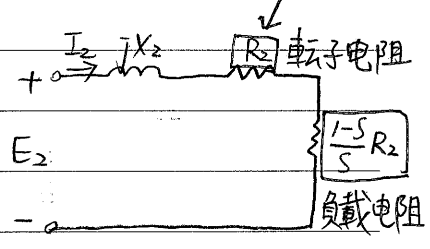
§Ch 2. 感應機

① 三相感应电动机等效电路



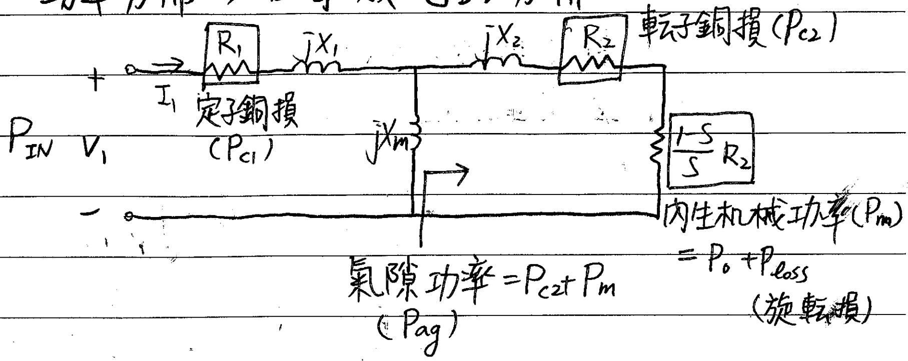
$\left[\begin{array}{l} a=1 \\ R_c \text{忽略} \end{array}\right.$





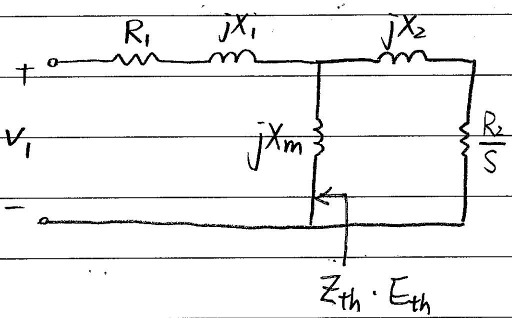
$$\frac{R_2}{S} = R_2 + \frac{1-S}{S} R_2$$

功率分佈 ⇒ 由等效电路分析



$$* \; P_{ag} : P_{c2} : P_m = 1 : S : (1-S)$$

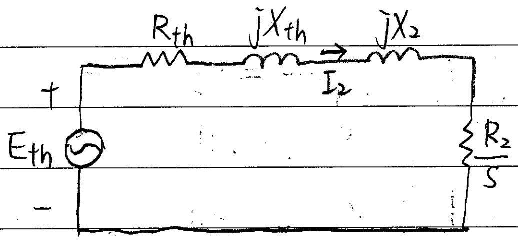
轉換 ⇒ 定子側看入，求戴維寧



$$Z_{th} = jX_m // (R_1 + jX_1)$$

$$= R_{th} + jX_{th}$$

$$E_{th} = V_1 \times \frac{jX_m}{R_1 + jX_1 + jX_m}$$



② 転矩
- 起动転矩
- 最大転矩之転差率
- $\boxed{\text{最大転矩}}$ T_{max}

$$T_{(感应)} = \frac{\boxed{P_{ag}}}{\omega_s} \quad 3 \times I_2^2 \times \frac{R_2}{S} = P_{ag}, \quad I_2 = \frac{E_{th}}{\sqrt{(R_{th}+\frac{R_2}{S})^2+(X_{th}+X_2)^2}}$$

$$T_o = \frac{P_o}{\omega_r} \qquad T = \frac{P_{ag}}{\omega_s} = \frac{P}{4\pi f} \times \frac{3\times E_{th}^2}{(R_{th}+\frac{R_2}{S})^2+(X_{th}+X_2)^2} \times \frac{R_2}{S}$$

$$\omega_s = \frac{2\pi}{60} N_s = \frac{2\pi}{60} \times \frac{120f}{P} = \frac{4\pi f}{P}$$

① $T_S(S=1) = \frac{P}{4\pi f} \times \frac{3E_{th}^2 R_2}{(R_{th}+R_2)^2+(X_{th}+X_2)^2}$

② $\boxed{\frac{R_2}{S} = \sqrt{R_{th}^2+(X_{th}+X_2)^2}}$

$$\Rightarrow S_{max,T} = \frac{R_2}{\sqrt{R_{th}^2+(X_{th}+X_2)^2}}$$ ※

③ 啟动

種類
- 鼠籠式 ⇒ 降低电压
- 繞線式 ⇒ 串接転子电阻

條件(目的)
- 降低啟动电流,($I_s\downarrow$)
- 增加啟动転矩,($T_s\uparrow$)

$$\downarrow I_2 = \frac{E_{th}\downarrow}{\sqrt{(R_{th}+\frac{\uparrow R_2}{S})^2+(X_{th}+X_2)^2}}$$

· 降低电压（鼠籠式）
- ① Y－Δ
- ② 一次側串接电阻（电抗）
- ③ 自耦 T_r

① Y－Δ

*

$$\frac{I_s(Y)}{I_s(\Delta)} = \frac{1}{3}$$

$$\frac{T_s(Y)}{T_s(\Delta)} = \frac{1}{3}$$

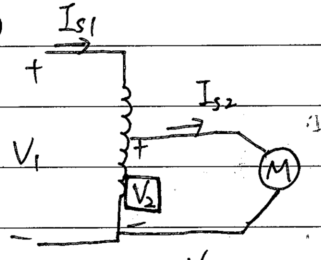
②
- 电源电压（V_1）
- 电动机电压（V_2）

$\therefore \frac{V_2}{V_1} = \frac{1}{a}$

$$I_s = \frac{1}{a} I_{s(全)}$$

$$T_s = \left(\frac{1}{a}\right)^2 T_{s(全)}$$

③



I_{s1} ⇒ 电源側电流

I_{s2} ⇒ 电动机側电流

$$a = \frac{V_1}{V_2}$$

*
- V_2 為 $\frac{1}{a}$ 倍全压电压
  ⇒ $I_{s1} = \left(\frac{1}{a}\right)^2 I_{s(全)}$
- V_2 為全压時
  ⇒ $I_{s1} = \frac{1}{a} I_{s(全)}$

$$T_s = \left(\frac{1}{a}\right)^2 T_{s(全)}$$

• 串接転子电阻
(繞線式)

$$* \quad \frac{R_2}{S_1} = \frac{R_2 + \boxed{R_s}}{S_2} \Rightarrow R_2\uparrow \rightarrow S\uparrow \rightarrow n\downarrow \text{ 転速控制}$$

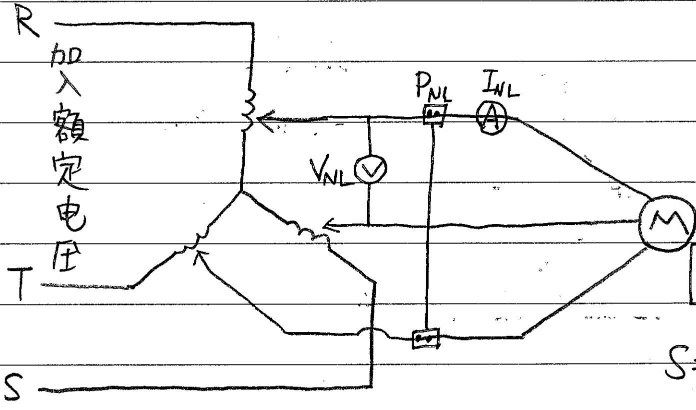
$$T = \frac{P}{4\pi f} \times 3I_2^2 \times \boxed{\frac{R_2}{S}}$$

(定值)

④ 試驗

- 無載 ⇒
  - 求旋転損
  - 求磁化电感
- 堵住転子 ⇒
  - 定子阻抗
  - 転子阻抗

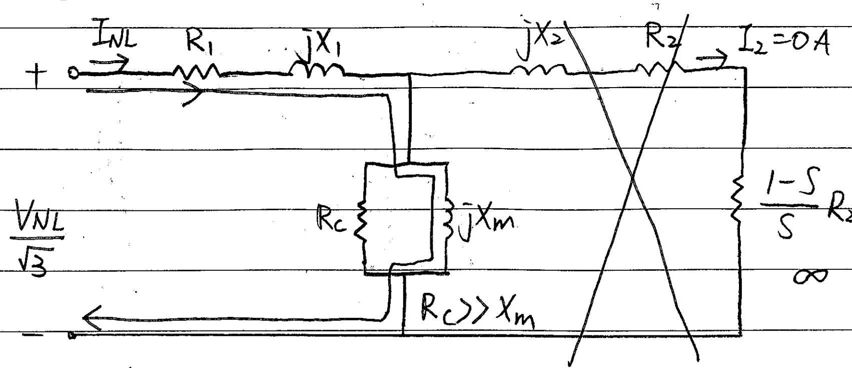
• 無載接線图:



$\boxed{S=0}$

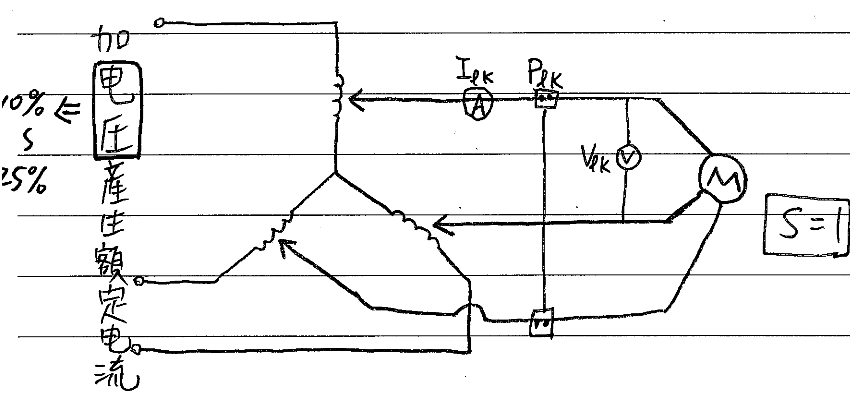
$$S = \frac{N_s - N_r}{N_s} = 0$$

電路图:

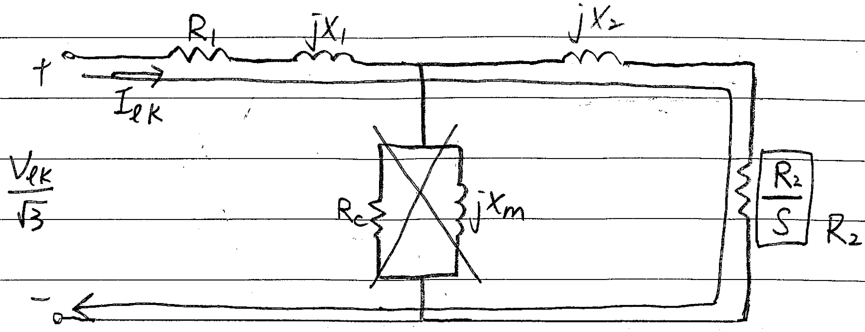


$$\left[\begin{array}{l} \dfrac{\frac{V_{NL}}{3}}{I_{NL}} = R_{Nl} + jX_{nl} = R_{nl} + j(X_1 + X_m) \\ R_{Nl} = \dfrac{P_{nl}}{3\times I_{nl}^2}, \quad \underset{(旋転損)}{P_{loss}} = P_{IN} - 3(I_{nl})^2 R_1 \end{array}\right.$$

• 堵住転子接线图:



電路图:



$$\frac{\frac{V_{\ell k}}{\sqrt{3}}}{I_{\ell k}} = (R_1 + R_2) + j(X_1 + X_2) \Rightarrow Z_{\ell k}$$

$$R_1 + R_2 = \frac{P_{\ell k}}{3(I_{\ell k})^2}$$

$$\boxed{X_1 + X_2} = \sqrt{Z_{\ell k}^2 - (R_1 + R_2)^2}$$

與頻率成正比

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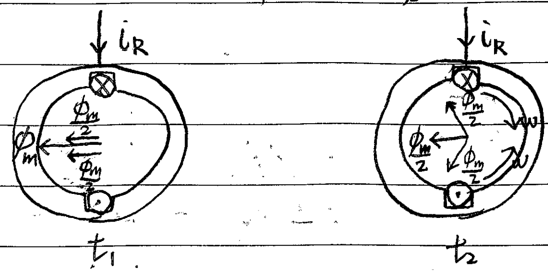
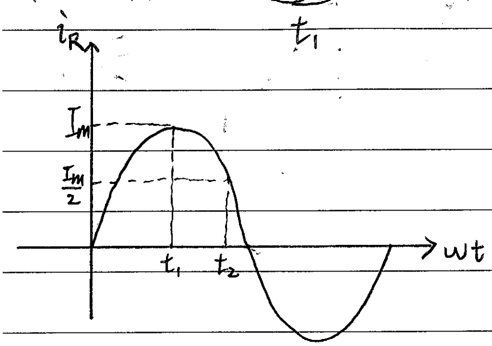
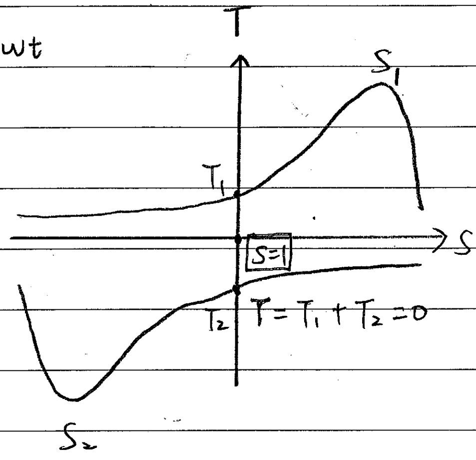
⑤ 單相感应电动机 ⇒ 無法自行啟动

（双旋転磁場理論）



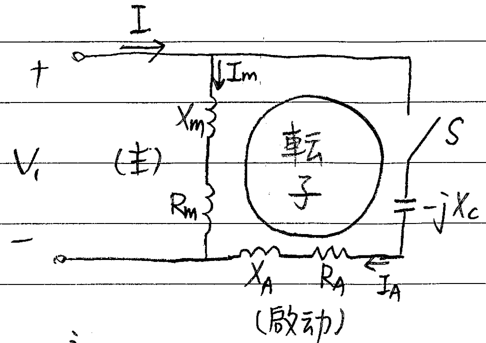


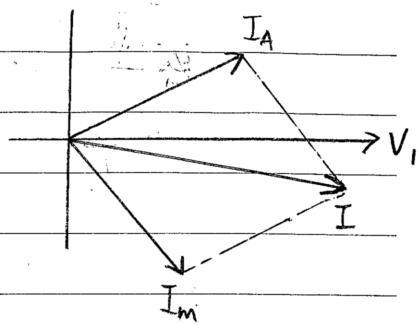


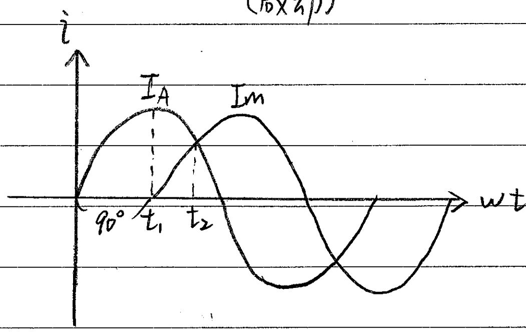
* 幫助啟动 ⇒ 產生兩次旋転磁場
  - 啟动电容式
  - 分相式 ⇒ 兩線阻相差 90° 电机角
  - 蔽極式

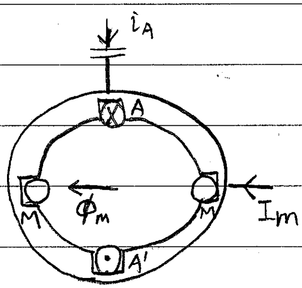
(I_A) (I_m)

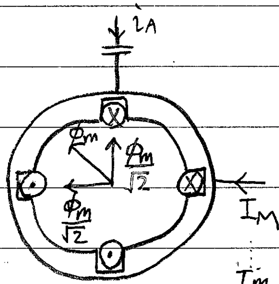
9. 啟动电容式（起动电流角主繞阻电流相差90°电机角）









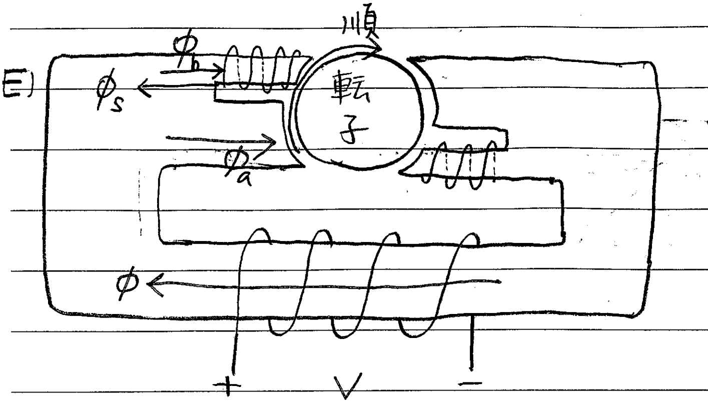


$t=1$ $\begin{cases} I_A = I_m \\ I_M = 0 \end{cases}$

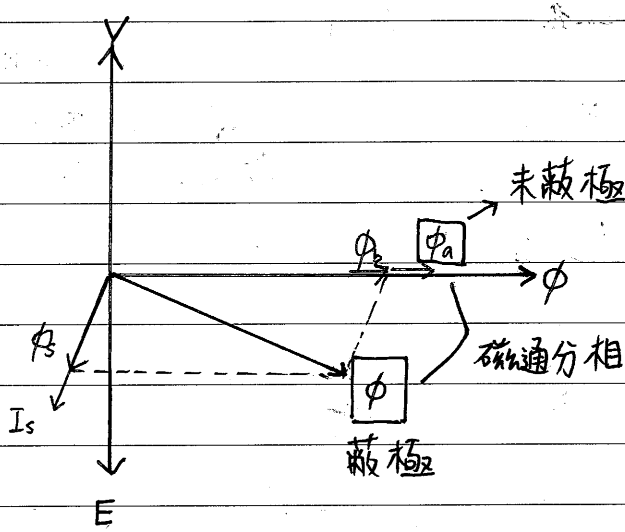
$t=2$ $\begin{cases} I_A = \dfrac{I_m}{\sqrt{2}} \\ I_M = \dfrac{I_m}{\sqrt{2}} \end{cases}$

※ $\boxed{X_c = X_A + \dfrac{R_M R_A}{X_M}}$

c. 蔽極式 ⇒ 短路線圈



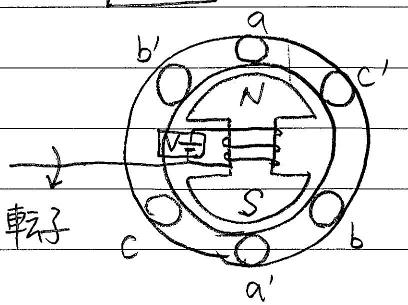
$$\phi = \phi_a + \phi_b$$



$$E = N\frac{\Delta\phi}{\Delta t}, \quad \phi\angle 0^\circ, \quad E\angle 90^\circ$$

§ Ch3. 同步發电机

① 原理

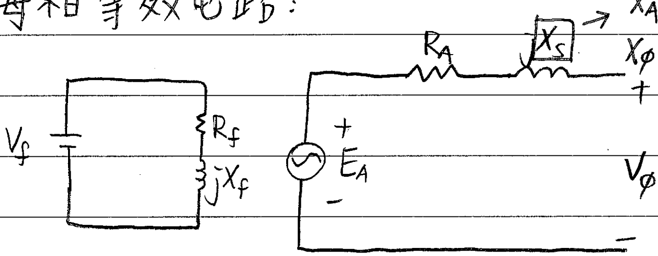


- 圓柱 ⇒ 高速 ⇒ 汽輪
- 凸極 ⇒ 低速 ⇒ 水輪

同步电抗

每相等效电路:

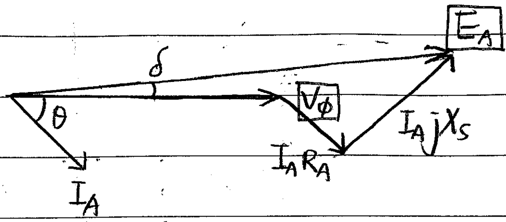
X_A : 电極反应电抗
X_ϕ : 漏磁通电抗



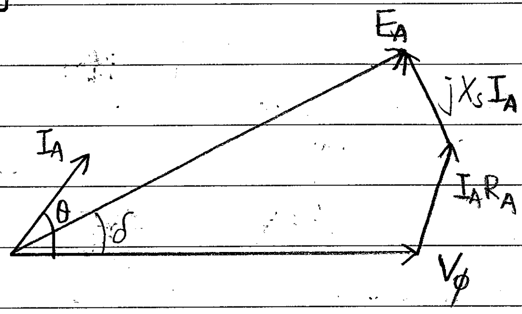
Date . .

② $\boxed{向量}$

落後：



超前



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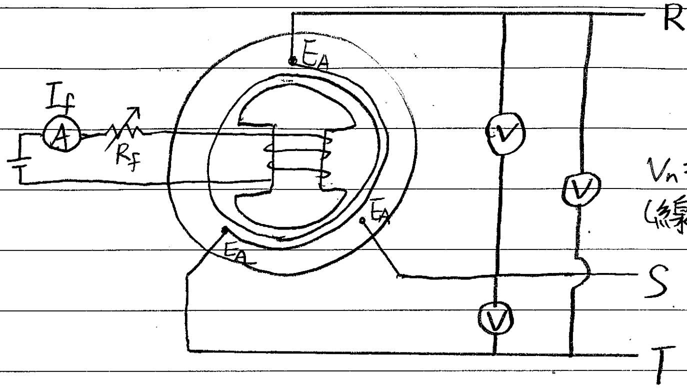
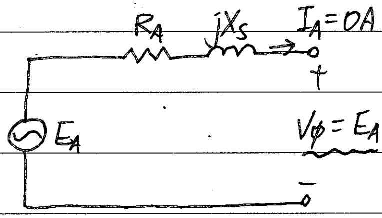
③ 試驗
- 開路 ⇒ 無載
- 短路

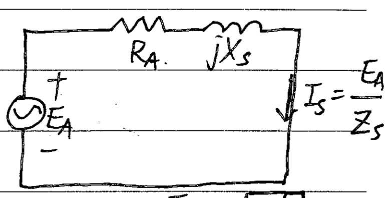


$V_n = \sqrt{3} E_A$
(線电压)

開路:

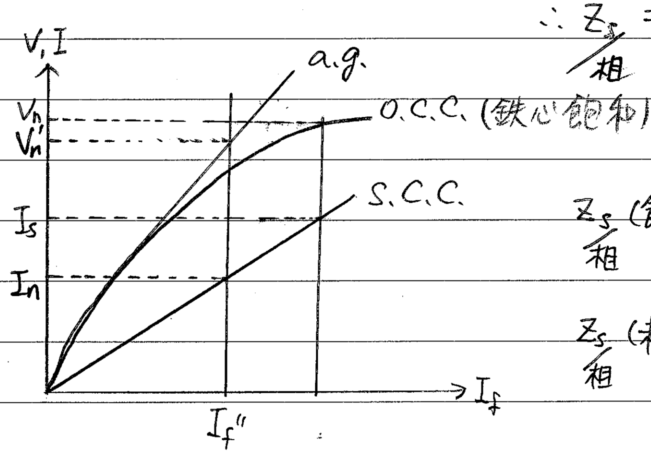


短路:



$\therefore Z_s/相 = \frac{E_A}{I_s} = \boxed{\frac{V_\phi}{I_s}}$

相同 I_f 下



$Z_s/相\ (飽和) = \frac{V_n/\sqrt{3}}{I_s}$

$Z_s/相\ (未飽和) = \frac{V_n'/\sqrt{3}}{I_n}$

短路比(SCR)

$$= \frac{\text{開路电压在}\boxed{\text{額定}}\text{下的場电流}}{\text{短路电流在}\boxed{\text{額定}}\text{下的場电流}}$$

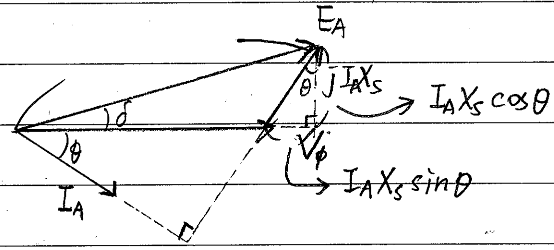
$$= \frac{I_f'}{I_f''} = \frac{I_s}{I_n} = \frac{\frac{1}{I_n} \times \frac{V_n}{\sqrt{3}}}{\frac{1}{I_s} \times \frac{V_n}{\sqrt{3}}} = \frac{Z_b}{Z_s} = \frac{1}{Z_{s(pu)}}$$

④ 电压調整率

$$VR\% = \frac{\boxed{E_A} - V_\phi}{V_\phi} \times 100\%$$

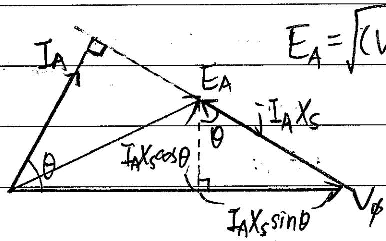
功因落後

$$E_A = \sqrt{(V_\phi + I_A X_s \sin\theta)^2 + (I_A X_s \cos\theta)^2}$$

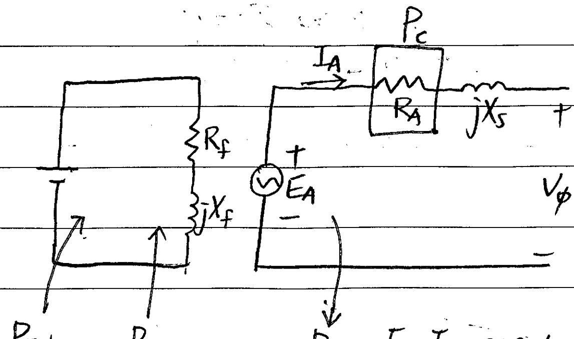


功因超前

$$E_A = \sqrt{(V_\phi - I_A X_s \sin\theta)^2 + (I_A X_s \cos\theta)^2}$$

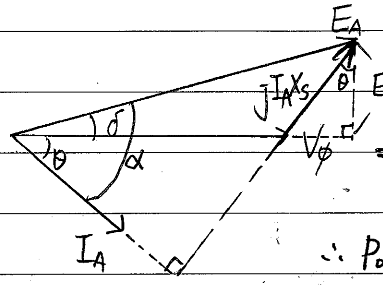


⑤ $\boxed{\text{功率分佈}}$ ⇒ 每相等效电路



$$P_e = E_A I_A \cos\alpha$$

$$P_o = V_\phi I_A \cos\theta = P_e - P_c$$



$$E_A \sin\delta = I_A X_s \cos\theta$$

$$\Rightarrow I_A\cos\theta = \frac{E_A \sin\delta}{X_s}$$

$$\therefore P_o = V_\phi I_A \cos\theta = \boxed{\frac{E_A V_\phi}{X_s}\sin\delta}$$

① 無角度
② 每相
③ $\frac{E_A V_\phi}{X_s}$ 最大

⑥ $\boxed{\text{並联運用}}$ ⇒ 电压 ⇒ $V(t) = V_m \sin(2\pi f t + \theta)$

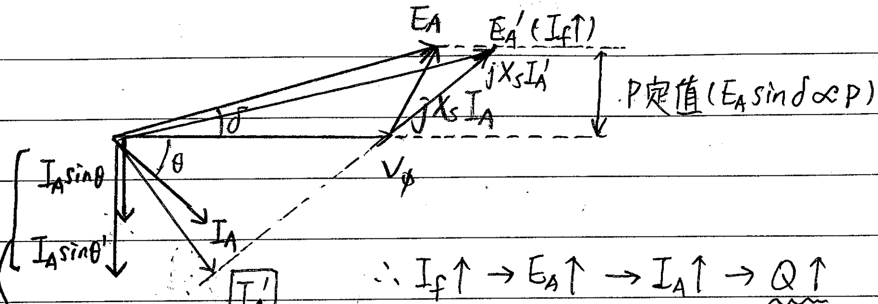
條件：① 感应电压大小相同
② 〃 波形 〃
③ 〃 頻率 〃
④ 〃 相位 〃
⑤ 〃 相序 〃

避免產生內部環流

Date . .

⑦ $\boxed{\text{負載分配}}$ ⇒ $\left[\begin{array}{l} I_f \Rightarrow \text{虛功率} \\ \underset{(f)}{N_s} \Rightarrow \text{實功率} \end{array}\right.$

$\boxed{\text{虛功率}}$ ⇒ $I_f \propto Q$ [條件：V_ϕ, P 定值]

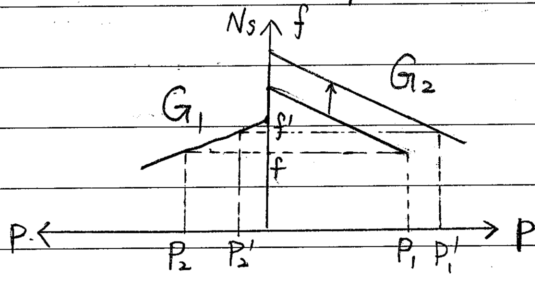


$\boxed{Q} \propto I_A\sin\theta$

$\therefore I_f\uparrow \rightarrow E_A\uparrow \rightarrow I_A\uparrow \rightarrow Q\uparrow$

$\boxed{\text{實功率}}$ ⇒ $N_s(f) \propto P$

$\left(N_s = \frac{120f}{P}\right)$



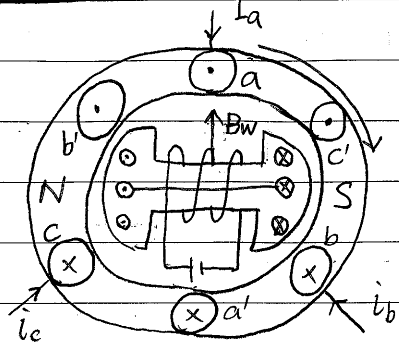
$N_s\uparrow \rightarrow f\uparrow$

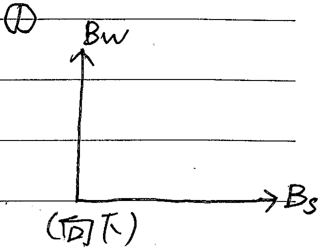
$$P_L = P_1 + P_2 = P_1' + P_2'$$

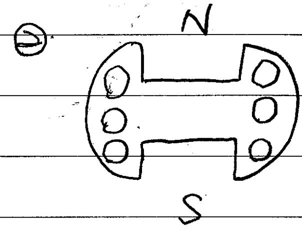
Date . .

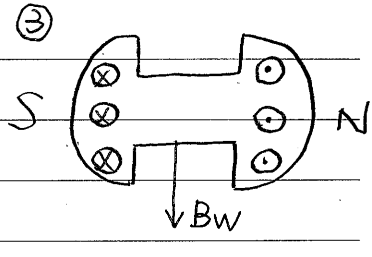
§Ch4. 同步電動機 ⇒ 無法自行啟動 ⇒ 阻尼繞阻

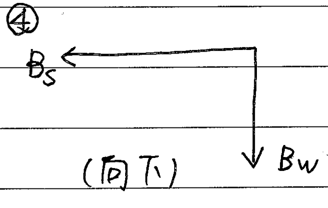
① 原理



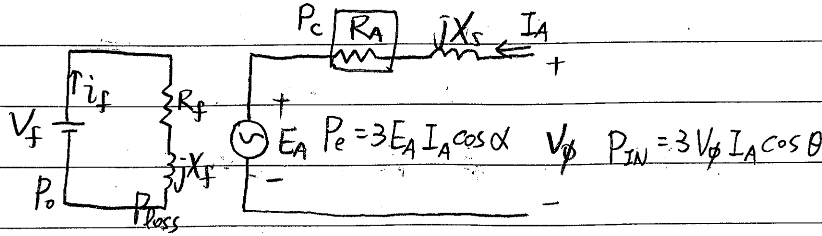




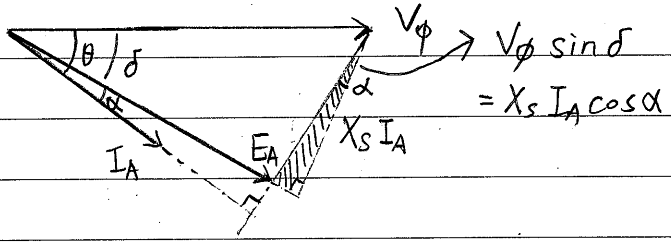




功率分佈(每相等效电路):



$P_o = P_e - P_{loss}$



不計 P_{loss} 時, $P_o = P_e$

$P_o = E_A I_A \cos\alpha$
(每相)

$$= E_A \frac{V_\phi \sin\delta}{X_s} = \boxed{\frac{E_A V_\phi}{X_s} \sin\delta}$$

Date . .

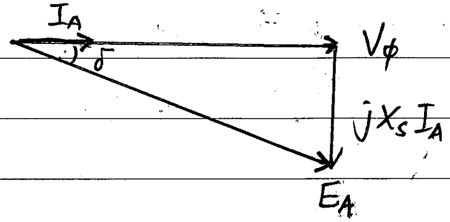
② 激磁特性

條件：端电压 (V_ϕ)，転矩為定值 (P)

目的：調整 I_A，$\cos\theta$

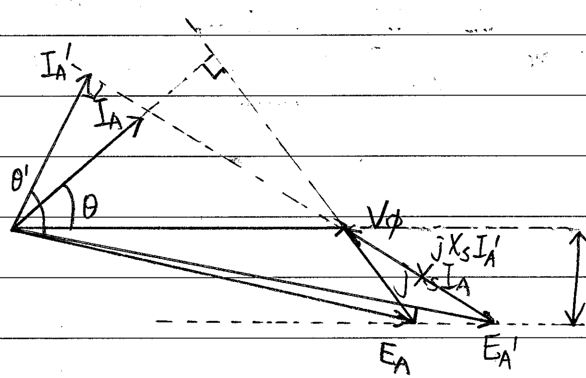
① 正常激磁 [$\cos\theta = 1$, I_A 最小]

調整 I_f 使 V_ϕ 与 I_A 同相位



② 过激磁 ($I_f\uparrow \rightarrow E_A\uparrow$)

[① $I_f\uparrow \Rightarrow I_A\uparrow$
② $I_f\uparrow \Rightarrow \theta\uparrow \Rightarrow \cos\theta\downarrow$]



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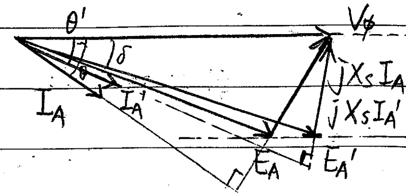
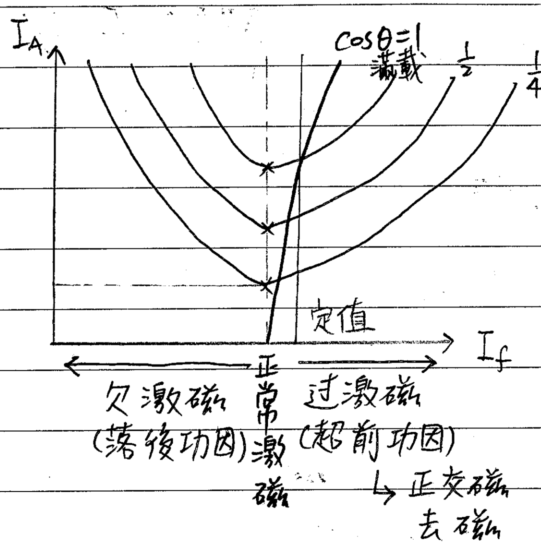
③ 欠激磁 ($I_f\downarrow \Rightarrow E_A\downarrow$)



① $I_f\uparrow \Rightarrow I_A\downarrow$

② $I_f\uparrow \Rightarrow \theta\downarrow \Rightarrow \cos\theta\uparrow$



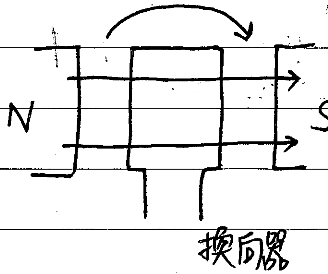
I_f定值, 增加負載

⇒ 功率因数由

超前 → 落後

§ Ch5. 直流機

① $\boxed{\text{產生感應電勢 } E_{av}}$



$$\phi_{(t)} = \phi \cos wt$$

$$e = -N\frac{d\phi}{dt} = \overbrace{\boxed{\phi w}}^{V_m}\sin wt$$

$(N=1)$

$$\therefore E_{av} = \underbrace{\frac{2V_m}{\pi}}_{\text{每匝平均电压}} \times \underbrace{\frac{Z_a}{2} \times \frac{1}{a}}_{\text{每个路径数之匝数}}$$

$$= \frac{2\phi w}{\pi} \times \frac{Z_a}{2} \times \frac{1}{a}$$

$$= \frac{2\phi 2\pi f}{\pi} \times \frac{Z_a}{2} \times \frac{1}{a}$$

$$= \frac{2\phi 2\pi \frac{pn}{120}}{\pi} \times \frac{Z_a}{2} \times \frac{1}{a}$$

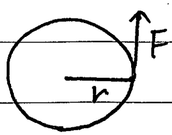
$$\frac{N_s}{60} \times \frac{P}{2} = f$$

$$= \boxed{\frac{PZ_a}{60a}} \times \phi n$$

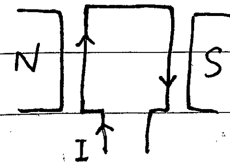
$$= K\phi n$$

② 産生転矩 (T)

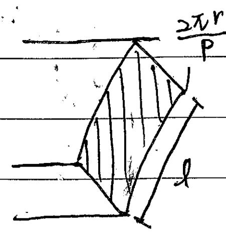
$$T = \boxed{F} \times r$$



$$F = \boxed{B}\, l\, \boxed{I}$$ (單一導体)



$$\therefore F = \frac{\phi}{A} \times l \times I \times Z_a$$



$$= \frac{\phi}{\frac{2\pi r l}{P}} \times l \times \frac{I}{a} \times Z_a$$

$$= \frac{P\phi}{2\pi r \cancel{l}} \times \cancel{l} \times \frac{I}{a} \times Z_a$$

$$= \frac{P\phi}{2\pi r} \times \frac{I}{a} \times Z_a$$

$$\therefore T = F \times r$$

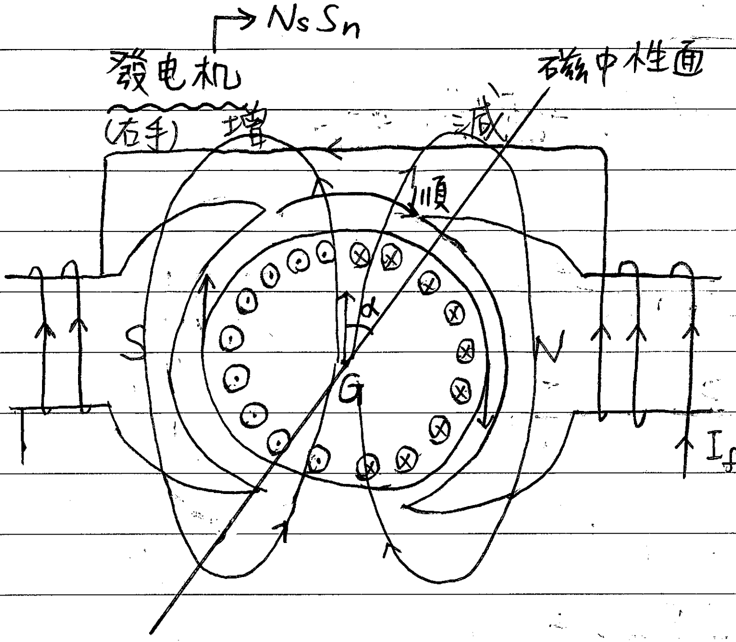
$$= \frac{P\phi}{2\pi r} \times \frac{I}{a} \times Z_a \times r$$

$$= \boxed{\frac{P Z_a}{2\pi a}} \times \phi \times I$$

$$= K\phi I$$

③ 电枢反应

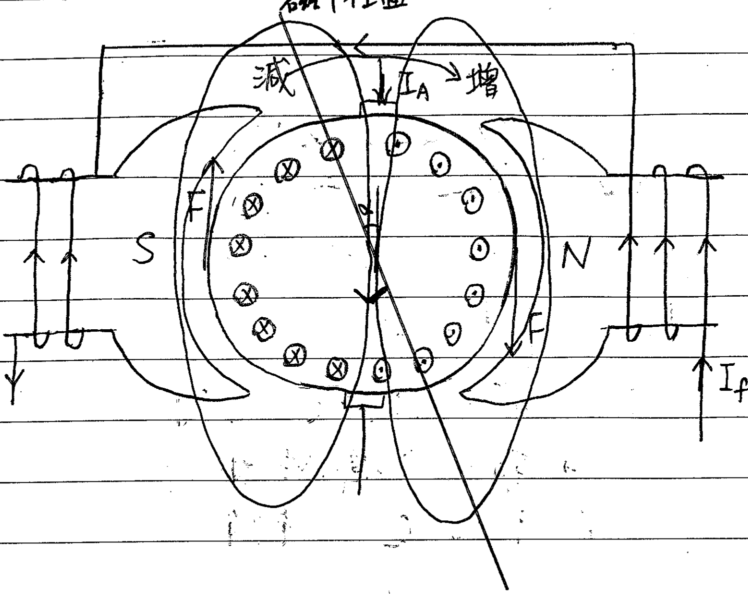
- 主磁場
- 电枢磁場 → 減弱 → 改善电枢反应



- 前極尖磁通減少
- 後極尖磁通增加
- 磁中性面 順 旋転方向移动
- 电刷 〃

Date . .

电动机（左手）→ $N_n S_s$



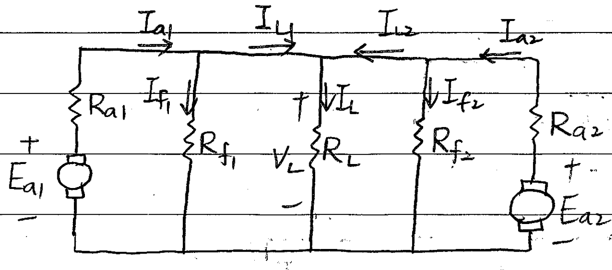
前極尖磁通增加
後極尖磁通減少
磁中性面 $\boxed{逆}$ 旋転方向移动
电刷 〃

△補償繞阻

△中間極

並联運用
- 分激式
- 積複激式

④ 分激式



條件：
- ① 端电压大小相同
- ② 端电压極性相同
- ③ $P_L = V_L I_L$（V_L 定值）
  $\therefore P_L \propto I_L$
  容量與負載电流成正比
- ④ 外部特性曲線相同

負載分配：

$$P_L \propto I_L \Rightarrow \frac{P_{L1}}{P_{L2}} = \frac{I_{L1}}{I_{L2}}$$

又 $E_A = V_L + I_a R_a$（E_A、V_L 定值）

$$\therefore \frac{I_{a1}}{I_{a2}} = \frac{R_{a2}}{R_{a1}}$$

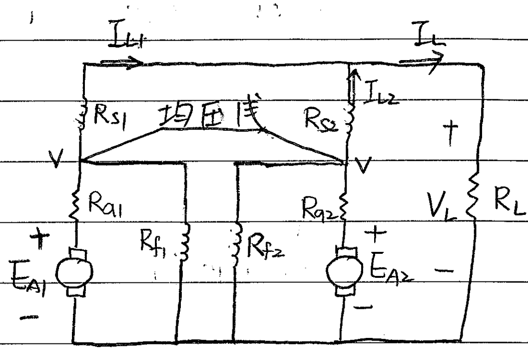
$$\Rightarrow \boxed{\frac{I_{L1}}{I_{L2}} = \frac{P_{L1}}{P_{L2}} = \frac{R_{a2}}{R_{a1}}}$$

Date . .

$\boxed{R_a \text{已知}}$ ⇒ 解联立，求 I_{L1}、I_{L2}

$$\begin{cases} I_L = I_{L1} + I_{L2} \\ V_L = E_{A1} - I_{L1}R_{a1} = E_{A2} - I_{L2}R_{a2} \\ (I_a \doteq I_L) \end{cases}$$

⑤ 積複激式

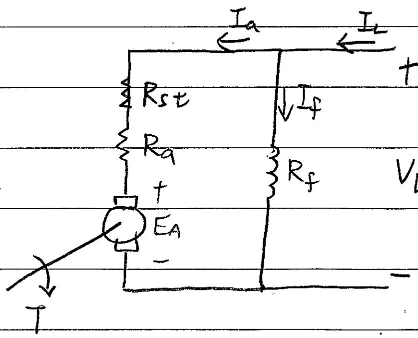


條件：
①
②
③
④ 分激式相同
⑤ 裝設均压线
⑥ $I_{L1}R_{s1} = I_{L2}R_{s2}$ ⇒ $\boxed{\dfrac{I_{L1}}{I_{L2}} = \dfrac{R_{s2}}{R_{s1}}}$

負載分配：$\boxed{\dfrac{I_{L1}}{I_{L2}} = \dfrac{P_1}{P_2} = \dfrac{R_{s2}}{R_{s1}}}$

⑥ $\boxed{\text{啟動}}$ ⇒

- 降低啟动电流 ⇒ 串接电阻
- 增加啟动転矩



$$n=0 \Rightarrow E_A = 0$$

$$\uparrow I_{as} = \frac{V_L - \cancel{E_A}^{\,0}}{R_a\downarrow} \quad \uparrow$$

$$R_{st} = \frac{V_L - E_A}{I_{as}} - R_a - R_s$$

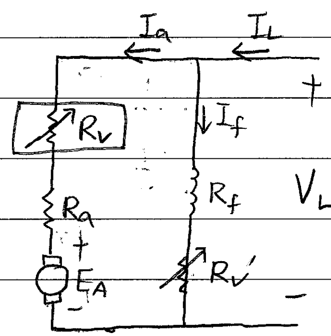
↳串激式

⑦ $\boxed{\text{速率控制}}$

$$E = K\phi n$$

$$\Rightarrow n = \frac{\boxed{V_L} - I_a\boxed{R_a}}{K\boxed{\phi}}$$

① 电枢电阻控制法



$$R_V\uparrow \rightarrow E_A\downarrow \rightarrow n\downarrow$$

$$R_V'\uparrow \rightarrow I_f\downarrow \rightarrow \phi\downarrow \rightarrow n\uparrow$$

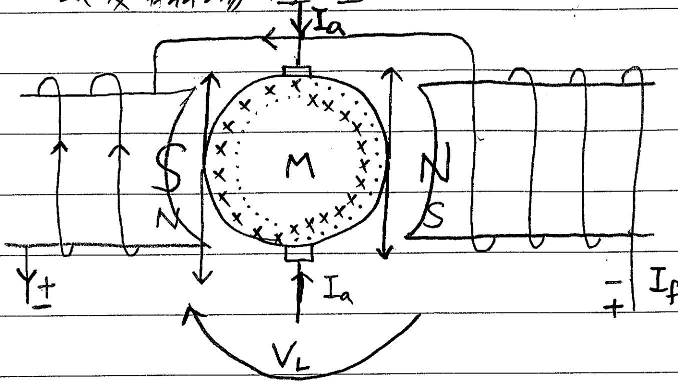
Date . .

⑧ 転向控制

⇒ 佛萊銘左手

⇒ 改変电極电流

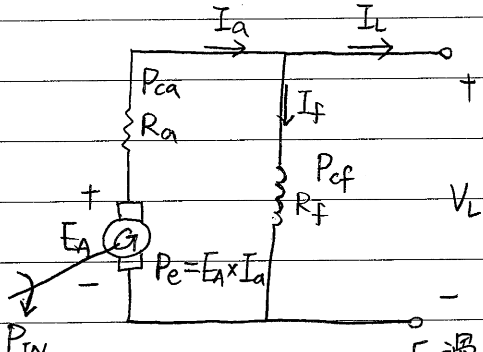
改変磁場極性



順時針

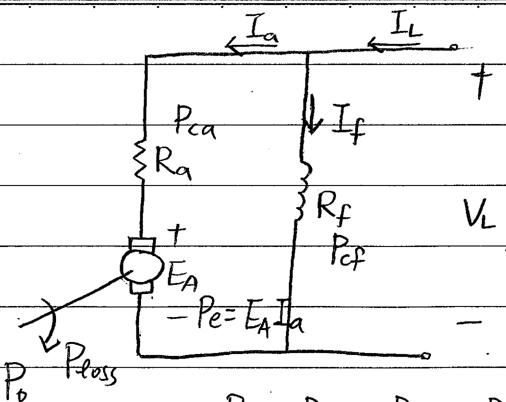
⑨ 功率分配 ⇒ 看等效电路

無載 ⇒ $I_a = I_f$ ($I_L = 0$)



$$P_o = P_e - P_{ca} - P_{cf}$$
$$= P_{IN} - P_{loss} - P_{ca} - P_{cf}$$

P_{loss} (旋転損) ⇒
- 鉄損
  - 渦流 $\propto n^2$
  - 磁滯 $\propto n$
- 机械損
  - 摩擦
  - 风阻



$P_{IN} = V_L I_L$

$$P_e = P_{IN} - P_{ca} - P_{cf}$$

$$P_o = P_e - P_{loss}$$

無載 $\Rightarrow P_{loss} = P_e$